Speech by Alexander Graham Bell, December 8, 1880

(3-1-35) Remarks of Alexander Graham Bell on the paper by Mr. W. H. Preece, on "The Photophone and the Conversion of Radiant Energy into sound", read before the Society of Telegrpah Engineers, London, December 8, 1880.

" Professor Alexander Graham Bell: It gives me great pleasure to have the opportunity of saying a few words to you upon matters not touched upon by Mr. Preece, although I would rather he had continued his discourse. It certainly is a very extraordinary s e nsation to hear a beam of sunlight laigh, cough and sing, and talk to you with articulate words; but when you come to understand how these results are accomplished, you see that the operation is a very simple one. Mr Preece has told us that the only substance yet known to us whose electrical resistance is effected by light is the substance selenium. When we look back upon the history of the discovery of this property, and realise that it was accidentally made while investigating the cause of an observed variability of conducting power, it seems difficult to believe that selenium is the only substance whose electrical resistance is effected by light; and the conviction grows that a persistent search will reveal other chemical elements or compounds possessing this property. Of course, the first substance to which we would turn would be the chemical neighbours of selenium — tellurium, sulphur, and phosphorus.

" Tellurium, we know, in the hands of Professor Adams has yielded indications of reduced resistance when exposed to light like selenium, although experiments recently made in America, at Yale College by Professor Wright, with tellurium, in the shape of a thin film deposited on glass, have yielded exactly contrary results, that is, the resistance has been increased by light instead of being reduced. In Washington I have, in conjunction with my associate, Mr. Sumner Tainter 2 sought to utilise tellurium in photophonic experiments, but our results have as yet been simply negative. The difficulties in the way of investigating changes resistance in tellurium are of the opposite nature to those encountered in studying similar changes in selenium. In the latter case the normal resistance is so great that refined methods have to be employed, and in the former case the resistance is so slight that equally delicate apparatus has to be employed. In our Experiments Mr. Tainter and I have been accustomed to cut a spiral groove in/a non-conducting surface, which groove was filled with tellurium. We thus obtained considerable surface and increased resistance, but we were unable to detect any change produced by light.

“ In the year 1839 George Knox announced that sulphur and phosphorus became conductors of electricity when fused, but the authority o f Faraday, who placed these substances amongst those which were non-conductors, both in the solid and liquid condition, seems to have overshadowed this statement, for their non-conducting nature seems still to be accepted without question.

“ I do not know how the matter may be in regard to phosphorus, but in respect to sulphur the statement of Knox has been verified in Washington by Mr. Tainter and myself. We have/found that the yellow liquid formed by melting flowers of sulphur is unmistakably a condition of condu c tivity, and that its conductivity increases with rise of temperature, until the liquid begins to change colour. The conductivity then ceases, and no amount of cooling or reheating seems to be able to - restore its conducting power. But if you heated melted flowers of sulphur to the point of highest conductivity, and then slowly cool, slowly the substance retains, in a solid condition, at ordinary temperatures, a percentage of its conducting power. This I look upon as the index that points the way to the util i zation of sulphur in place of 3 selenium, although as yet we have failed to obtain indications of change of resi s tance produced by light.

“ We all know that when a current of electricity is passed around the coils of an electro-magnet, a molecular disturbance is produced in the iron core of the magnet, and that if the current is interrupted a large number of times per second, the rapid succession of molecular changes in the soft iron can be observed as sound by placing the ear in close contact with the iron core. A musical tone is heard, the pitch of which depends upon the rapidity of the interruption of the electrical current. While discussing this fact with Mr. Sumner Tainter it occurred to us that a molecular disturbance, however produced, should in a similar way be audible as sound when rapidly intermitted. We know that a molecular disturbance was produced by the action of light upon crystalline selenium, and it therefore seemed likely that when this substance was exposed to an intermittent beam of light a musical tone might be perceived, without any electrical , apparatus, by placing the ear in contact with the selenium. On performing the experiment with bars or masses of selenium, no sound was heard. We also listened to masses of iron and other substances under the action of an intermittent beam of light, in the hope that we might be able to hear the succession of molecular disturbances produced by the ray, but without success. When the crystalline selenium was connected in circuit with a battery and telephone, very perceptible musical tones were produced from the telephone when the selenium was exposed to an intermittent beam of light. It was our custom to stop the sound by shading the selenium with the hand. But on using a piece of hard rubber or ebonite to shade the light it was found that this apparently opaque substance did not entirely cut off the sound audible from the telephone in connection with the selenium. It seemed as if an invisible beam passed through the ebonite 4 or hard rubber, impinged upon the s elenium, and, being rendered intermittent by such a perforated wheel as you see here to-night, produced a musical tone in the telephone. This tone could be at once cut off by placing the hand in the path of the invisible beam.

“ When we cut off the beam of sunlight before reaching the first lens by interposing the hard rubber, an invisible beam passed through the lens, was brought to a focus at the perforated wheel, was rendered parallel by the next lens and projected along a room for several yards, and was then brought to a second focus by another lens upon a piece of selenium in circuit with a telephone and battery, and a musical tone was clearly produced. In this case the rotation wheel interrupted what was then an invisible beam. This seemed to indicate some peculiar property about hard rubber or ebonite, and bearing in mind the experiment of which I have told you, of listening directly to crystalline selenium and other substances, the idea occurred to listen to the hard rubber while an intermittent beam of sunlight was falling upon it. The result was extraordinary. A clear musical tone was immediately perceived. By using the sheet of hard rubber as a diaphragm , and listening through a hearing tube when the intermittent beam of light fell upon the diaphragm, the tone produced was immensely icreased in volume. We then discussed the Question whether this property belonged wholly to hard rubber, or whether it was due to the form in which thr ubber was presented to the beam of light. In our earlier experiments we had used masses of crystalline selenium and other substances, but without success, and it seems probable that the molecular disturbanc e produced by light in opaque bodies was chiefly a surface action, and that the vibration had to be mechanically transmitted through the mass of the substance in order to effect the ear, and that this 5 might be the reason why better results followed when the substance was used in the shape of a thin diaphragm. We constructed a thin diaphragm of selenium, and on placing it on the apparatus we found a similar, though less audible effect produced. We then tried diaphragms of other substances. I have some forty or fifty of the original diaphragms used on exhibition here: they are of different materials, and a ll produced musical tones when under the influence of an intermittent beam of sunlight. Al metals, paper, gutta percha, different kinds of wood, even leather, and in fact all the substances we have tried in the shape of thin diaphragms, have yielded sounds. One very interesting and suggestive peculiarity showed itself in these experiments, and that was the difference in the intensity of the sound audible from discs exactly similar in every respect but of different material. This suggests a wide field for investigation.

In discussing with Mr. Sumner Tainter the necessity of using a thin diaphragm, we were led to another form of the experiment still more interesting. If the effect of intermittent sunlight was to produce a surface vibration, we were evidently listening at the wrong side of the diaphragm. If we could have our ear in relation to the illuminated side, the sound should be louder. We therefore varied the experiment by throwing the light into the interior tube. By bringing the beam of light to a focus just on the interior of the tube, the rays diverging from the focal point struck the inside of the tube, and our ear was then in relation to the air with the illuminated surface. By throwing a beam of sunlight into this tube, a very clear musical tone was produced. We have tried substances of different kinds in tubular forms, and from every substance so tried we have produced a musical tone. I may say that it is not even necessary to use an artificial tube, but on throwing the intermittent beam of sunlight into the air itself, a 6 musical tone can be produced. From the large number of experiments made by Mr. Sumner Tainter and myself, we have felt ourselves justified in announcing this as a general property of all matter; but of couse it is impossible to obtain all substances in the shape of tubes or diaphragms; and another form of the experiment has occurred to me since coming to Europe, by which the generality of the phenomena may be tested The sun fortunately came out for about an hour in Paris, and I was able to test the experiment. A transparent vessel, such as a glass test tube may be taken, into which substances can be placed in any physical condition (solid, liquid or gaseous). Connect the open mouth of the test tube with a hearing tube, and listen while you submit the contents of the test tube to the action of an intermittent beam of light. All the substances tried so far have given sounds, except chlorate of potash in a state of powder, plain water, and air. I have tried 30 or 40 different substances. Crystals of sulphate of copper gave out clear musical tones. A whole cigar placed in the test tube emitted a beautiful sound: and even tobacco-smoke puffed into the test tube yielded a sound. The best results obtained have been from little chips of wood inserted in the test tube. I have since had the opportunity of repeati ing these experiments with the electric light at the Royal Institution, and I think I was able to demonstrate the existence of these sounds to the satisfaction of Professor Tyndall and one or two others who listened to them.

“ I will not take up your time any longer, but simply say that any questions that it is within my power to answer concerning the experiments made in America, I shall be happy to do my best to reply to. ”